EXECUTIVE SUMMARY

Fluorescent lamp ballasts are used to operate fluorescent lamps in commercial and industrial buildings. Three types of ballasts are available for purchase: energy efficient magnetic (EEM), cathode cutout (CC) and electronic ballasts. Electronic ballasts are available in either rapid start (RS) or instant start (IS) mode. The major categories of lamps are four foot T12s, eight foot T12s and T12HOs, and four foot T8s. Bureau of the Census data show that the total market for power factor[1] corrected (power factor > 85%) fluorescent lamp ballasts (which are the subject of this analysis) in the U.S. in 1996 was about 72 million units, of which approximately 41% were electronic. Figure 1 shows ballast sales over the last several years. Shipments data obtained from NEMA for 1995 (1996 data were not available), showed that 50% of the 66.6 million ballasts shipped (of the type analyzed in this report) were electronic.

During the 1980s, several states enacted laws requiring the use of energy-efficient magnetic (EEM) ballasts instead of standard magnetic ballasts. State standards were followed by a Federal standard requiring EEM ballasts for certain T12 lamps.

Utility demand-side management (DSM) and EPA Green Lights programs have promoted sales of the more efficient electronic ballasts. Due to projected declines in DSM spending and projected decline in electricity prices, it is unknown whether the rapid growth in sales of electronic ballasts will continue into the future. Therefore, in this report, several scenarios for conversion (early replacement) of magnetic to electronic fluorescent lamp ballasts in existing buildings are considered.

This report contains an analysis that compares energy efficient magnetic (EEM), cathode cutout (CC), electronic rapid start (ERS) and electronic instant start (EIS) ballasts in their operation of several lamp types. The analyses include cost-efficiency, life-cycle cost, payback period, national energy consumption and savings, net present value to the nation, utility impact and environmental impact. Input data were obtained from many sources, including the National Electrical Manufacturers Association (NEMA) and its members. Several meetings to discuss data requirements and results, including public workshops, were held in 1994, 1995, 1996 and in 1997.

Life Cycle Cost and Payback Period Analyses

Table ES-1 summarizes the life-cycle cost (LCC) results for each lamp/ballast combination studied. For some product classes (3F40T12, 3F40T12/ES and 4F40T12) some lamp/ballast combinations are not included because there is only one technology (ERS) for which life-cycle cost data are available; that is, there are no single energy efficient magnetic or cathode cutout ballasts available in those product classes. For such product classes, there was no comparison of life-cycle costs under operation with a single electronic ballast to that with a combination of magnetic or

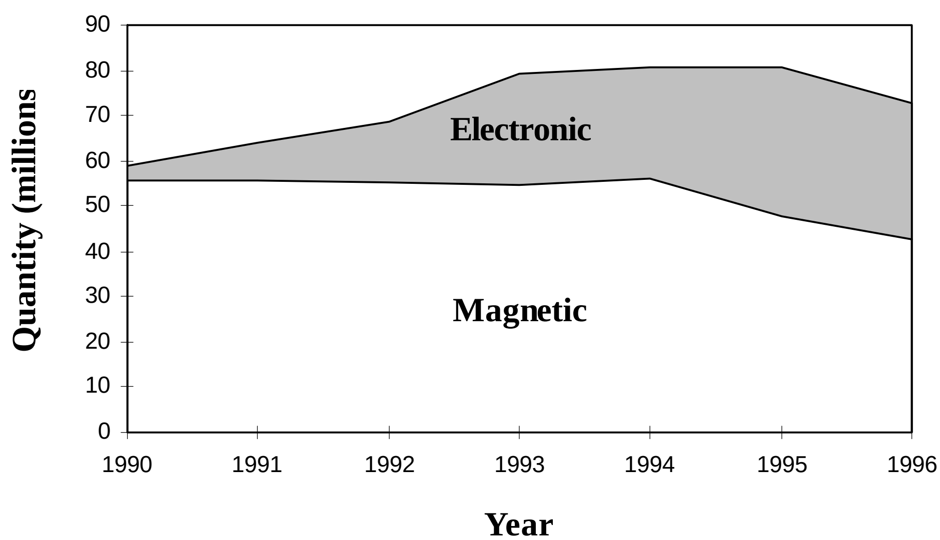
[1] Power factor is defined as the cosine of the angle of phase shift between the voltage and current drawn by an operating electrical device.

cathode cutout ballasts (Combinations of such ballasts are taken into account in the national energy use calculations.) In addition to calculating LCC for average values of electricity price, ballast lifetime and operating hours, sensitivity analyses were performed to determine the impact of varying each of these three parameters. The average electricity price estimated for 2001 is $0.075/kWh in 1995$ for the commercial sector and $0.048/kWh in 1995$ for the industrial sector. Annual ballast lifetime is 45,000 hours. Equipment prices are found in Chapter 4. Average annual lighting operating hours are 3600, 4000, and 5000 hours for four foot T12 and T8 lamps, eight foot T12 lamps, and eight foot high output (HO) T12 lamps, respectively.

Two types of LCC sensitivities were performed; these are high and low point sensitivities around the average parameter value and also sensitivities using distributions for the input parameter. For the high/low sensitivities for electricity prices, sensitivities were performed at $0.055 and $0.105/kWh for the commercial sector and $0.03 and $0.065/kWh for the industrial sector. For annual operating hours, sensitivities were performed at 2500 and 8000 hours. For ballast life, sensitivities were performed at 33,000 and 80,000 hours. Sensitivity to discount rate (the average is 8% real, or 8% above the inflation rate) was also determined for two other discount rates (4% and 12% real) and are shown in Chapter 4.

An example demonstrates how to use Table ES-1. For ballasts operating 2 F40T12 energy saver lamps (2F40T12/ES), there are three alternate technologies or design options. For average values of the input parameters, the life-cycle cost is $202 per year, $195 per year and $191 per year for EEM, CC and ERS ballasts, respectively. Therefore, the minimum LCC occurs with an ERS ballast. The sensitivity of the average LCC to the three parameters shown in Table ES-1 is shown in the low and high columns for each parameter.

Figure ES-1: U.S. Fluorescent Lamp Ballast Shipments[2]



Source: Dept. Of Commerce Data

[2]power factor corrected ballasts only

Table ES-1 Life Cycle Cost Sensitivities (1995$)

	Annual Lighting Hours			Ballast Life (hrs)			Electricity Price		
Ballast System	Lo	Avg	Hi	Lo	Avg	Hi	Lo	Avg	Hi
Commercial Sector	2500	3600	8000	33000	45000	80000	5.5	7.5	10.5
1 F40T12 (Comm.)									
EEM	137	157	191	132	157	199	129	157	200
CC	141	160	193	142	160	202	133	160	201
ERS	**129**	**146**	**175**	**124**	**146**	**181**	**124**	**146**	**180**
1 F40T12/ES (Comm.)									
EEM	119	136	164	114	136	171	112	136	171
CC	120	136	162	121	136	170	114	136	168
ERS	**112**	**126**	**149**	**108**	**126**	**154**	**108**	**126**	**153**
2 F40T12 (Comm.)									
EEM	209	243	299	201	243	312	193	243	317
CC	206	237	289	206	237	304	191	237	306
ERS	**204**	**234**	**286**	**196**	**234**	**297**	**190**	**234**	**301**
2 F40T12/ES (Comm.)									
EEM	175	202	248	168	202	258	162	202	262
CC	170	195	237	170	195	249	158	195	250
ERS	**167**	**191**	**232**	**161**	**191**	**241**	**157**	**191**	**243**
1 F32T8 (Comm.)									
EEM	119	135	162	114	135	168	113	135	167
ERS	**112**	**126**	**150**	**108**	**126**	**155**	**108**	**126**	**154**
EIS	116	131	157	114	131	160	114	131	158
2 F32T8 (Comm.)									
EEM	186	214	262	179	214	273	173	214	276
CC	183	209	254	183	209	267	171	209	267
ERS	**174**	**200**	**243**	**168**	**200**	**252**	**164**	**200**	**254**
EIS	177	204	249	173	204	256	169	204	257
3 F32T8 (Comm.)									
ERS	**228**	**262**	320	**220**	**262**	333	**212**	**262**	337
EIS	228	263	**322**	223	263	**331**	216	263	**334**
4 F32T8 (Comm.)									
ERS	283	326	400	**272**	326	417	**261**	326	424
EIS	**279**	**323**	**397**	**272**	**323**	**409**	262	**323**	**414**
2 F96T12 (Comm.)									
EEM	396	459	566	389	459	585	369	459	593
EIS	**379**	**437**	**536**	**374**	**437**	**553**	**356**	**437**	**559**
2 F96T12/ES (Comm.)									
EEM	310	358	438	305	358	454	288	358	463
EIS	**294**	**337**	**410**	**290**	**337**	**424**	**276**	**337**	**430**
Industrial Sector	2500	5000	8000	33000	45000	80000	3.0	4.8	6.5
2 F96T12HO (Ind.)									
EEM	412	526	583	438	526	706	392	526	652
CC	411	518	572	433	518	706	391	518	638
ERS	**404**	**511**	**564**	**429**	**511**	**679**	**388**	**511**	**626**
2 F96T12HO/ES (Ind.)									
EEM	357	452	500	379	452	604	340	452	558
CC	350	439	483	369	439	594	335	439	538
ERS	**344**	**431**	**474**	**364**	**431**	**568**	**331**	**431**	**524**

Table ES-2 shows the payback periods for several lamp/ballast combinations. Average values for equipment price, electricity price, ballast lifetime and operating hours are used to calculate average payback periods. Sensitivities are performed for high and low values of lighting hours and electricity price. Details of these calculations and definitions are found in Chapter 4.

Table ES-2: Payback Period (Years) for Lamp/Ballast Combinations

	Annual Lighting Hours			Electricity Price		
Ballast System	Lo	Avg	Hi	Lo	Avg	Hi
Commercial Sector	2500	3600	8000	0.055	0.075	0.105
1 F40T12 (Comm.)						
EEM	-	-	-	-	-	-
CC	96.3	66.9	30.1	Infinite	66.9	18.7
ERS	**5.5**	**3.8**	**1.7**	**5.2**	**3.8**	**2.7**
1 F40T12/ES (Comm.)						
EEM	-	-	-	-	-	-
CC	17.6	12.2	5.5	24.6	12.2	7.0
ERS	**5.8**	**4.0**	**1.8**	**5.5**	**4.0**	**2.9**
2 F40T12 (Comm.)						
EEM	-	-	-	-	-	-
CC	6.8	4.7	2.1	8.2	4.7	**2.9**
ERS	**6.3**	**4.4**	**2.0**	**5.9**	**4.4**	3.1
2 F40T12/ES (Comm.)						
EEM	-	-	-	-	-	-
CC	**5.6**	**3.9**	**1.8**	6.2	**3.9**	**2.5**
ERS	**5.6**	**3.9**	**1.8**	**5.3**	**3.9**	2.8
1 F32T8 (Comm.)						
EEM	-	-	-	-	-	-
ERS	**3.8**	**2.6**	**1.2**	**3.6**	**2.6**	1.9
EIS	4.3	3.0	1.4	6.6	3.0	**1.7**
2 F32T8 (Comm.)						
EEM	-	-	-	-	-	-
CC	7.1	4.9	2.2	9.2	4.9	2.9
ERS	2.7	1.9	0.8	**2.5**	1.9	1.3
EIS	**2.3**	**1.6**	**0.7**	2.8	**1.6**	**1.0**
3 F32T8 (Comm.)						
ERS	-	-	-	-	-	-
EIS	Undefined	Undefined	Undefined	Undefined	Undefined	**imm.**
4 F32T8 (Comm.)						
ERS	-	-	-	-	-	-
EIS	**imm.**	**imm.**	**imm.**	Undefined	**imm.**	**imm.**
2 F96T12 (Comm.)						
EEM	-	-	-	-	-	-
EIS	**3.7**	**2.6**	**1.2**	**3.5**	**2.6**	**1.8**
2 F96T12/ES (Comm.)						
EEM	-	-	-	-	-	-
EIS	**3.8**	**2.7**	**1.2**	**3.6**	**2.7**	**1.9**
Industrial Sector	2500	5000	8000	3.0	4.8	6.5
2 F96T12HO (Ind.)						
EEM	-	-	-	-	-	-
CC	27.5	13.7	8.6	Infinite	13.7	3.7
ERS	**5.9**	**3.0**	**1.8**	**4.7**	**3.0**	**2.2**
2 F96T12HO/ES (Ind.)						
EEM	-	-	-	-	-	-
CC	6.4	3.2	2.0	22.7	3.2	**1.8**
ERS	**4.8**	**2.4**	**1.5**	**3.8**	**2.4**	**1.8**

Energy Efficiency Levels

Six energy efficiency levels (which group the technologies for each product class) were chosen to compare several levels of potential energy savings from fluorescent lamp ballast efficiency improvements and to compare economic parameters such net present value (see below). The efficiency levels are organized so as to provide increasing energy savings at higher levels, and where possible, to group like technologies together, such as cathode cutout or electronic rapid start ballasts. Note that for some classes of ballasts, some technologies are not available in the market or are not feasible. We describe the six energy efficiency levels below.

Level one is comprised of non-electronic ballasts. Where cathode cutout ballasts are available they are chosen, if they are not available (one lamp F32T8 and two lamp F96T12 ballasts), then there is no change from the baseline. For three and four lamp F40T12 and F32T8 systems, EEM and CC ballasts are not available; for the consumer analysis their fixtures contain combinations of one and two lamp ballast types. Combinations of ballasts are not considered in the life-cycle cost analyses.

Level two is comprised of a combination of non-electronic and electronic ballasts. The cathode cutout ballast is retained for one and two lamp T12 systems; this provides a non-electronic ballast for the replacement market and for use with reduced wattage energy saver lamps which may have starting problems with electronic ballasts. The other lamp/ballast combinations use electronic ballasts. All T8 lamps employ rapid start electronic ballasts. At level 2, about 13% of the present total market would be converted from magnetic to electronic ballasts in 2000.

Level three is comprised of electronic ballasts, primarily rapid start types. Electronic instant start ballasts are used for the two lamp F96T12 system because the rapid start ballast type is not available. At this level, about 55% to 60% of the present total market would be converted from magnetic to electronic by 2000.

Level four is very similar to level three; the only difference is that for T8 lamps electronic instant start ballasts are substituted for electronic rapid start ballasts. The instant start ballasts are not always preferred because of reduced lamp life in the instant start mode relative to the rapid start mode, especially if there is increased switching due to the presence of occupancy sensors. The reduced lamp life is accounted for in the economic analyses.

Two alternative efficiency levels (variations of 1 & 2) were also added to the original four. They were used in only selected parts of the analysis. Alternative level one (A1) is the same as level one except for the ballast that operates the 2F96T12HO lamps, which is changed from a cathode cutout to an energy efficient magnetic ballast. Alternative level two (A2) is the same as level two except that for three and four lamp T12 lamps, the efficiency level remains at cathode cutout rather than changing to electronic rapid start.

National Energy Savings and Net Present Value

Table ES-3 shows the results of a national consumer analysis that estimates cumulative national energy savings and national net present benefit to consumers. Five base case scenarios at four main efficiency levels were analyzed as described fully in Chapter 5. These five scenarios are distinguished by different assumptions about conversion rates (early replacement of T12 magnetic ballast systems by T8 electronic ballast systems) and future electricity prices. The two alternative efficiency levels were analyzed only in combination with the "Constant Conversion" base case scenario, as described in Chapter 5.

Table ES-3: Summary of Interior Lighting Energy Savings and Net Present Values of Efficiency Levels for Fluorescent Ballasts Purchased from 2001-2030 All Scenarios

Efficiency Level	1	2	3	4
Energy Savings (Quads Primary)				
Constant Conversion Scenario	0.8	2.0	2.1	2.3
No Conversion Scenario	2.7	5.1	5.3	5.5
High Conversion Scenario	0.4	1.4	1.5	1.7
GRI Constant Conversion Scenario	0.8	2.0	2.1	2.3
GRI High Conversion Scenario	0.4	1.4	1.5	1.7
Net Present Values (billions 1994$ @ 7% discount rate)				
Constant Conversion Scenario	0.6	3.0	3.5	3.5
No Conversion Scenario	1.6	5.6	5.7	5.8
High Conversion Scenario	0.3	2.2	2.5	2.5
GRI Constant Conversion Scenario	0.4	2.5	2.9	3.0
GRI High Conversion Scenario	0.3	1.9	2.1	2.1

Since the future of voluntary programs is not known, a number of scenarios were analyzed. An example for level 3 shows how to interpret these results. The cumulative energy savings range from 1.5 to 5.3 quads and the NPV ranges from 2.1 to 5.7 billion dollars. The discount rate is 7% real, which represents a societal discount rate and is therefore different from the 8% consumer discount rate used in the life-cycle cost analysis. It is likely that the actual impacts on energy consumption and NPV of a mandatory program to improve energy efficiency will fall within these ranges, respectively. It can be seen from this table that the potential changes in electricity prices represented by the Gas Research Institute (GRI) electricity price forecast have little impact on energy saving potentials of various efficiency levels. Such changes do affect the monetary values of electricity savings, thus the net present values of efficiency levels would be affected.

Environmental Impacts

Table ES-4 summarizes the results of the environmental impact analysis for one of the efficiency levels, level 3. The reduction in power plant emissions of sulfur oxides, nitrogen oxides and carbon dioxide are shown for level three. The chapter on environmental assessment shows similar data for all four efficiency levels.

Table ES-4 Reduction of Pollutants for Fluorescent Ballasts - Energy Efficiency Level 3 Constant Conversion Scenario

SO_2

Year	Abated from Power Plants		Abated from Building		Total Reduction in Emissions		Reduction as a % of Power Plant Emissions
	kt	Thousand short tons	kt	Thousand short tons	kt	Thousand short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	18.10	19.95	-0.13	-0.15	17.96	19.80	0.50
2010	25.57	28.17	-0.13	-0.15	25.43	28.03	0.74
2015	21.26	23.43	-0.13	-0.15	21.13	23.29	0.64
2020	16.91	18.64	0.00	0.00	16.91	18.64	0.53
2025	14.63	16.12	0.00	0.00	14.63	16.12	0.47
2030	12.51	13.79	0.00	0.00	12.51	13.79	0.43

Cumulative SO2 reduction (kt): 528 (short tons): 581 000

NOx

Year	Abated from Power Plants		Abated from Building		Total Reduction in Emissions		Reduction as a % of Power Plant Emissions
	kt	Thousand short tons	kt	Thousand short tons	kt	Thousand short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	15.59	17.18	-0.24	-0.26	15.35	16.92	0.47
2010	23.24	25.61	-0.28	-0.31	22.96	25.30	0.70
2015	19.85	21.87	-0.24	-0.26	19.61	21.61	0.60
2020	15.66	17.26	-0.18	-0.20	15.48	17.06	0.50
2025	12.29	13.54	-0.14	-0.15	12.15	13.39	0.43
2030	10.24	11.28	-0.14	-0.15	10.10	11.13	0.39

Cumulative NOx reduction (kt): 469 (short tons): 517 000

CO_2

Year	Abated from Power Plants		Abated from Building		Total Reduction in Emissions		Reduction as a % of Power Plant Emissions
	Mt	Million short tons	Mt	Million short tons	Mt	Million short tons	
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	4.57	5.04	-0.26	-0.29	4.31	4.75	0.39
2010	6.96	7.67	-0.31	-0.34	6.65	7.33	0.59
2015	6.33	6.98	-0.26	-0.29	6.07	6.69	0.51
2020	5.54	6.10	-0.19	-0.21	5.35	5.89	0.43
2025	5.14	5.67	-0.14	-0.16	5.00	5.51	0.38
2030	4.97	5.48	-0.14	-0.16	4.83	5.32	0.35

Cumulative CO2 reduction (Mt): 154 (short tons): 170 000 000